



**AGS VICTORIA 2016 SYMPOSIUM**  
**Excavations and slope stability**  
**in Melbourne geology:**  
**experiences and recent developments**

Wednesday, 16 November 2016, 12:00pm – 7:00pm  
Engineers Australia, 600 Bourke Street, Melbourne



**AUSTRALIAN GEOMECHANICS SOCIETY**  
**VICTORIA CHAPTER**

# WELCOME

The Victorian chapter of the Australian Geomechanics Society (AGS) is pleased to welcome you to this half-day symposium titled "Excavations and slope stability in Melbourne geology: experiences and recent developments".

Since the publication of the "Engineering Geology of Melbourne" in 1992, both the geotechnical profession and Melbourne has undergone significant change. Urban sprawl over the past few decades has seen increasing development in the hillside areas in the Dandenong and Mornington Peninsula regions. This coupled with changes to the regulatory environment and the introduction of the Landslide Risk Management Framework by the AGS in 2007 has changed the way in which local and state government as well as geotechnical practitioners manage and assess slope stability.

In addition to development in hillside areas, significant development in the inner parts of Melbourne has posed many challenges for excavations not just in the soft soils of the Yarra Delta but also the weak rock of the Melbourne Formation.

This symposium seeks to bring together practitioners from consulting, construction and academia to share and discuss their experiences on the separate, but related, topics of excavation and slope stability. Best practices, case histories and innovative solutions for dealing with these challenges will be presented and discussed, with a particular emphasis on local geotechnical issues.

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Ramtin Tajeddin

# INTEGRATION OF HISTORIC BASEMENTS

Chris Lyons.

<sup>1</sup>Associate, Arup, 1 Nicholson Street, East Melbourne, VIC 3002, PH (03) 9668 5623; email: [chris.lyons@arup.com](mailto:chris.lyons@arup.com)

## ABSTRACT

Basement construction and retention solutions in urban environments are constrained by numerous factors both internal and external to the site. This case study reviews the different challenges encountered at a basement construction site in Melbourne. A detailed review of historic site information provided a basis to optimise the ground parameters and integrate historic temporary works into the retention design. Collaborative working between the lead contractor, geotechnical engineer and structural engineer enabled existing basement structures to be used as temporary and/or permanent works, as well as reducing temporary retention works to provide project cost savings and reduce project risks.

*Keywords:* Melbourne Geology, historic, basements, complex, collaborative

## 1 INTRODUCTION

The primary objectives of urban basement projects are typically to;

- Maximise the basement extent;
- Provide cost effective retention solutions;
- Protect surrounding property/infrastructure;
- Integrate retention solutions into the construction methodology;

In a complex urban environment, typical constraints which need to be overcome as part of the design include;

- Historic buried obstructions such as buried footings, backfill or temporary works;
- Property boundary constraints;
- Surcharge loading on the basement retention from adjacent buildings and roads;
- Subsurface spatial constraints including basements, tunnels and utilities;
- Environmental considerations including noise and vibration; and
- Geological conditions.

This paper looks at a basement project in Melbourne and demonstrates the value of a detailed review of historic site information, developing a site specific geological model and collaborative working between the lead contractor, geotechnical engineer and structural engineer to develop effective basement retention solutions to reduce project costs and risk.

## 2 SITE DESCRIPTION

The site is approximately 58m long by 25m wide, with the eastern boundary fronting onto Russell Street in the Melbourne CBD. The

northern and southern site boundaries are bounded by Donaldson Lane and Portland Lane respectively, both of which are approximately 5m wide. The western boundary at the rear of the site is bounded by a 2m wide services easement. The buildings to the north and south range from two to six stories tall with a combination of single level, half level and no basements. The building to the west (rear) of the site has nine stories above ground and three basement levels.

### 2.1 Ground Conditions

The geology below the site is Silurian aged Melbourne Formation, consisting of residual soil / extremely weathered rock to a depth of 1.3m to 3.0m depth, over highly weathered siltstone/sandstone which reduces in weathering and increases in strength with depth. The top 0.5 to 1.0m of the subsurface profile consists of historic fill (asphalt, brick, crushed rock and fill).

Groundwater readings taken over a one year period were relatively consistent within each of the four standpipes around the site, with an overall range of 7 to 10m below ground surface, with the deepest readings below the deepest basement (typically >1.5m below the basement finished floor level).

## 3 EXISTING BUILDING

The existing structure was built in 1976 and consisted of a cinema complex of six large auditoriums spread over three levels above ground and one level below ground. The basement depth increased from approximately 1.5m depth at the rear of the building to 8m

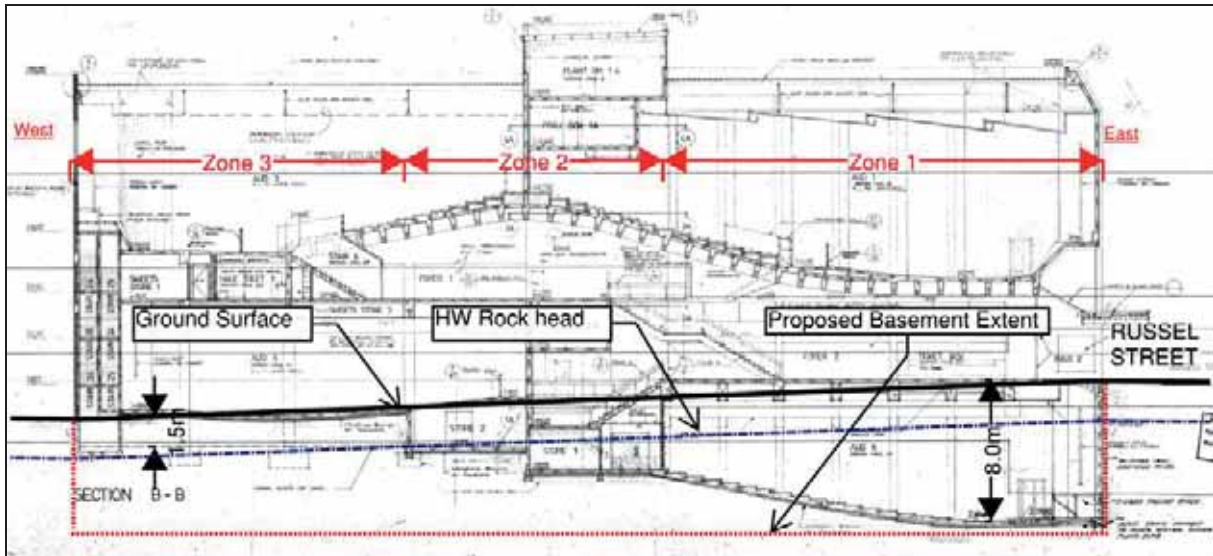


Figure 1, typical cross section through the existing building showing the cinema auditoriums and varying basement depth.

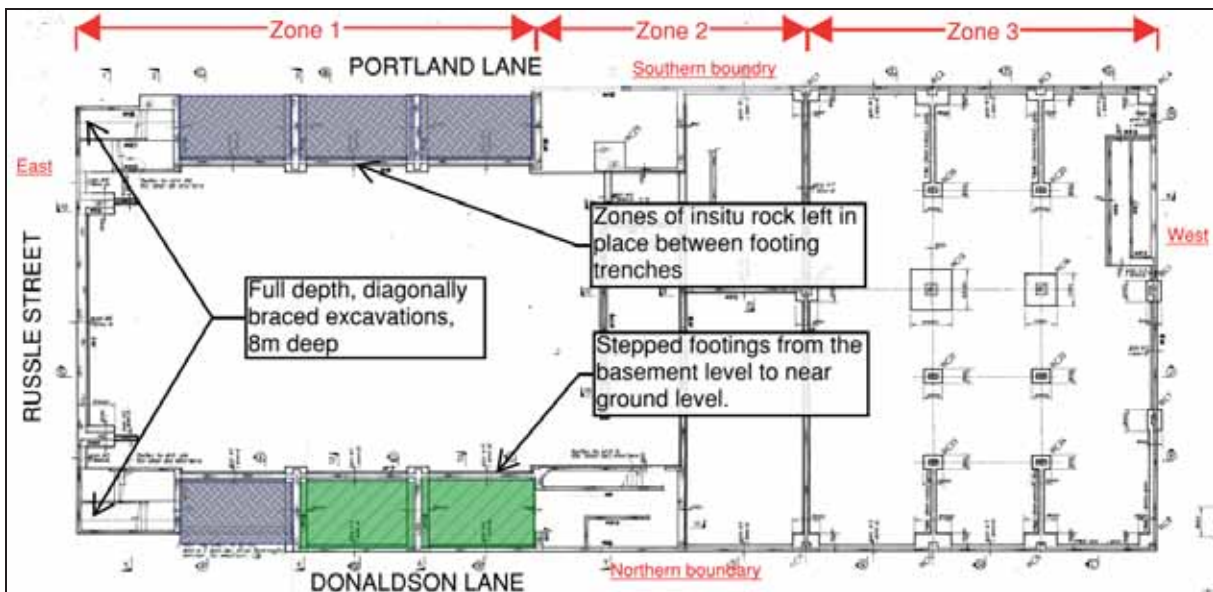


Figure 2 Existing building foundation layout plan with zones of insitu rock and stepped footings on the sides of the deeper part of the excavation in Zone 1 (Note the orientation of this figure is the opposite of Figure 1).

depth to the front of the building on Russell St (Figure 1).

The existing basement was excavated with a variety of techniques to suit the excavation depth and presence of nearby buildings and infrastructure. A layout of the basement foundations are shown in Figure 2. Key features of the construction methodology used affecting the proposed project are:

- The corner bracing and use of UB steel columns as temporary works (Figure 3); and
- The excavation of trench/stepped footings to support above ground structures while maintaining stability of adjacent structures (Figure 4).



Figure 3 Original basement excavation showing the 250UB channels as part of the temporary works.



Figure 4 Trench excavations for footings adjacent to the southern boundary to maintain external support to the adjacent ground and structures. A completed footing and wall with starter bars can be seen on the right of the image. The inferred typical rock dip direction is indicated.

#### 4 TENDER RETENTION SOLUTION

The tender reference solution consisted of a nine meter deep basement excavation with the following retention:

- On the eastern boundary (Russell Street), providing temporary ground anchors to support the existing basement walls;
- On the northern and southern sides of the site: A conventional 600mm dia bored pile wall with sprayed concrete panels along the full length of the property boundary, with a single row of ground anchors; and
- On the western boundary a 900mm diameter cantilever piled wall was proposed as the presence of an existing nearby basement restricted the use of ground anchors.

The piled walls were proposed to provide permanent lateral support to the basement

once the floor slabs were in place. The existing basement walls were not accepted as part of the new basement permanent retention solution as they did not meet current design standards and/or the project design life.

The successful contract for the development was won by Built Holdings Ltd Pty, who engaged Arup to provide detailed design basement retention services.

#### 4.1 Basement Construction Methodology

A successful retention solution needs to be integrated with the development construction methodology. The methodology developed during tendering consisted of;

- Progressive demolition of the existing building and backfilling of the basement with the demolition debris to the exiting ground level. The debris would support the existing basement walls once the ground floor slab was removed;
- Installation of retention piles around the basement perimeter with the piling rig sitting within the site footprint;
- Staged excavation, anchor installation and placement of sprayed concrete to the design excavation level;
- An earth/debris ramp to remain in the basement to provide access from the excavation floor to Russell Street; and
- Construction of foundations and subsequent bottom up construction with distressing of temporary anchors.

#### 5 CONSTRUCTION RETENTION SOLUTIONS

Through a detailed review of the historic building information and working with the contractor and structural engineer to address the varying site challenges and effectively integrate the retention works into the project, various retention solutions were developed around the site.

##### 5.1 Russell St Frontage

The existing basement wall along the central portion of the eastern frontage (Russell St) was the main cinema auditorium with a clear vertical span of 8m propped at the top and bottom by the ground floor and the basement foundation slab respectively. The wall was a 500mm thick reinforced concrete wall designed to span the large distance, however the removal of both the ground floor and basement

slab required a temporary retention solution to support the wall. A widely spaced anchored solution (4m vertically, 3m horizontally) was developed by assessing the capacity of the wall and sizing the anchors to match the load. The final anchor locations were modified to accommodate services in Russell St, the layout of the permanent basement walls and provide anchor-head access for de-stressing. Inspections prior to, during and post retention confirmed the wall had performed adequately. Working with the structural engineer it was agreed this wall could be adopted as part of the permanent works, removing the need for a new structural wall and increasing the basement space.

However, the northern and southern ends of this wall formed part of the basement stairwells which provided intermediate levels of restraint and as a result the walls were only 200mm thick (Figure 2) with significantly less structural capacity. Initial analysis indicated the temporary retention required either multiple rows of ground anchors or internal diagonal props which would have conflicted with the proposed construction methodology.

A closer review of the historic project drawings indicated that temporary works included 250UB channels which were installed to enable temporary lagging to be placed and support the diagonal propping used during the original basement construction (Figure 5 and 6). A review of historic construction photos verified these channels were installed as indicated on the temporary works drawings. A revised design for the capacity of the existing basement was completed using the additional structural capacity (allowing for corrosion) of these columns to reduce the number of anchors required. As a risk mitigation measure in the case the UB's were cut, corroded or could not be relied upon, calculations were completed to verify the serviceability (working) actions were within the unfactored structural capacity of the wall to mitigate the risk of failure.

During building demolition, the top of the UB's were exposed and inspected by structural engineers to assess corrosion and confirm the connection details were consistent with the temporary works drawings. The existing basement walls were also inspected during construction to identify any structural distress.

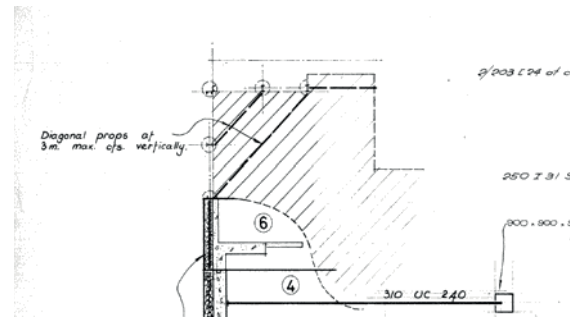


Figure 5 Temporary works drawings showing the location of temporary 250 UB 31 channels.

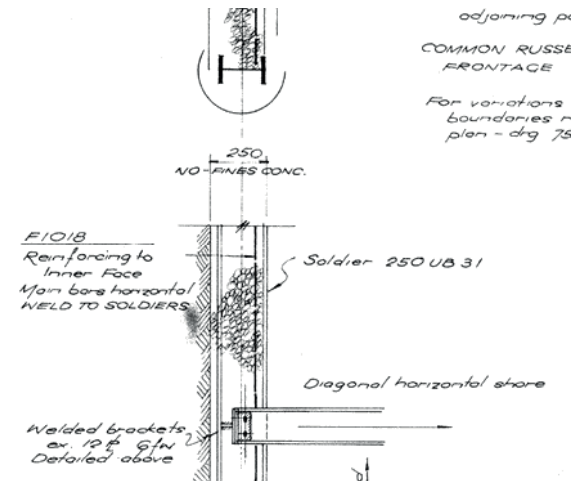


Figure 6 Temporary works drawings showing the temporary 250 UB 31 channel details.

## 5.2 Donaldson and Portland Lane Retention

The retention design along Donaldson and Portland Lane was influenced by the shape and depth of the existing basement, construction staging considerations and rock bedding orientation. Due to the different retention challenges along the basement, three retention solutions were developed as described below.

Over the rear (western) third of the basement (Zone 3, refer Figure 2), the existing basement walls abut the property boundary and extend to 2-3m depth. Along this extent it was proposed to locally break out the basement walls and floor slabs with an excavator to enable the installation of 600mm dia retention piles to below the final excavation level. The retention piles were supported by a single row of anchors installed during the basement excavation.

Over the middle third (Zone 2), the existing basement walls abut the property boundary and extend down to approximately 4-6m below ground level. In this zone it was not practical to break out areas for the piles or core through

the concrete walls or base slab. An alternative retention solution was adopted to provide programme savings and reduce programme risk, consisting of:

- Installation of two rows of stressed ground anchors through the existing wall and using the wall as the retention facing; then
- underpinning the existing walls with a sprayed concrete wall (2-4m high) with ground anchors to provide temporary support to the final excavation level.

To meet the project requirements, a new structural wall was cast in front of the existing wall to provide the permanent basement retention. Through coordination with the structural engineers, the underpinning walls were designed to provide support for the temporary excavation and act as part of the permanent basement wall to provide cost and programme savings during construction.

Over the front third of the basement (Zone 1), the existing basement walls are offset from the site boundary and therefore the conventional bored pile anchored retaining wall could be constructed. However, the presence of footings from the demolished buildings extending back to the property boundary (Figure 2 and 4) restricted pile locations, and while analysis showed that smaller diameter piles at closer spacing would provide cost savings, the arrangement would conflict with the footings and more widely spaced (1.6m to 2.4m), 600mm dia piles were instead adopted.

As is often the case in complex urban locations, piling obstructions (including temporary works from the deep basement to the west) and historic filling activities resulted in modification to the design onsite and at several locations around the basement piles could not be installed and alternative anchored solutions were developed.

Below Portland Lane, an existing Citi Power Utility tunnel which was approximately 2m in diameter with varying depth further complicated the layout, length and orientation of ground anchors, particularly in Zone 2. Combined with the presence of nearby basements and buried services, retention designs were forced to regularly vary along the site.

### 5.3 Rear wall retention

The proposed cantilever retention wall along the rear of the property was reviewed in a joint manner between the contractor, structural engineer and geotechnical engineer to assess alternative solutions. A review of the construction drawings of the adjacent building supported by engineering calculations indicated the existing basement could stand unsupported, thus removing the requirement for retention piles along this boundary.

### 5.4 Design optimisation

The historic development photos provide a valuable reference source for the orientation of the rock bedding and condition of the rock mass, indicating that the rock bedding dipped from south to north into the site at approximately 60°-70°. This defect dip angle was consistent with the defects in the investigation boreholes around the basement and published geological information.

Design parameters for the Silurian Melbourne formation rock mass were assessed using the Hoek-Brown failure criterion fitted to the Mohr-Coulomb failure envelope for defects entering into and out of the excavation as summarised in Table 1. The confidence in the dip direction provided by the site photos enabled refined retention solution to be adopted on the northern and eastern boundaries, reducing pile longitudinal steel by 40% and anchor loads/lengths. Additionally the confidence in the rock defects enabled the free length of ground anchors to be reduced compared to the common practice of extending anchors past a 45° line from the toe of the excavation.

As the orientation of bedding can vary significantly in the Melbourne Formation, and there is the risk of shear zones or similar defects, the designs were checked for an unfactored ULS case of adverse defect being encountered using the parameters provided (Table 1). The analysis verified that if unexpected ground conditions did occur the retention would remain stable until retention mitigation measures (backfilling, anchors or temporary props) could be adopted. Periodic inspections of the exposed rock face were completed to inspect for adverse ground conditions as part of the design verification during construction.

*Table 1: Highly to Moderately Weathered Melbourne Formation design parameters*

Unit	Unit weight, $\gamma$ (kN/m <sup>3</sup> )	Friction angle, $\phi'$ (deg)	Cohesion, $c'$ (kPa)	Deformation Modulus, $E_{\text{mass}}$ (MPa)
Bedding dipping into the slope	21	25	20	100
Bedding dipping out of the slope	21	25	50	100
Unexpected shear zones/defects	21	23	5	100

## 6 CONCLUSIONS

Basement retention systems in urban environments are complicated by multiple factors including adjacent properties and infrastructure, subsurface conditions, existing structures and construction methodology. Our role as engineers is to facilitate effective solutions which meet these challenges. This paper provides an example where the detailed review of historical site information, a clear understanding of the site geology and collaborative working between the lead contractor, geotechnical and structural engineers has enabled alternative designs to be adopted with confidence, achieving project programme and cost objectives while effectively addressing design and construction risk.

Tender stage designs on complex urban projects often overlook producing an integrated approach considering the various design elements and project constructability. This often results in larger project risks, contingencies and missed opportunities. Integrating constructability earlier in the project process is the most effective way of mitigating these risks and producing cost effective solutions in these complex environments.

## 7 ACKNOWLEDGEMENTS

The author would like to thank the lead contractor (Built Holdings Pty Ltd) and structural Engineer (Arup).

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